Nano-wettability: *macro* to *micro* to *nano* scale control

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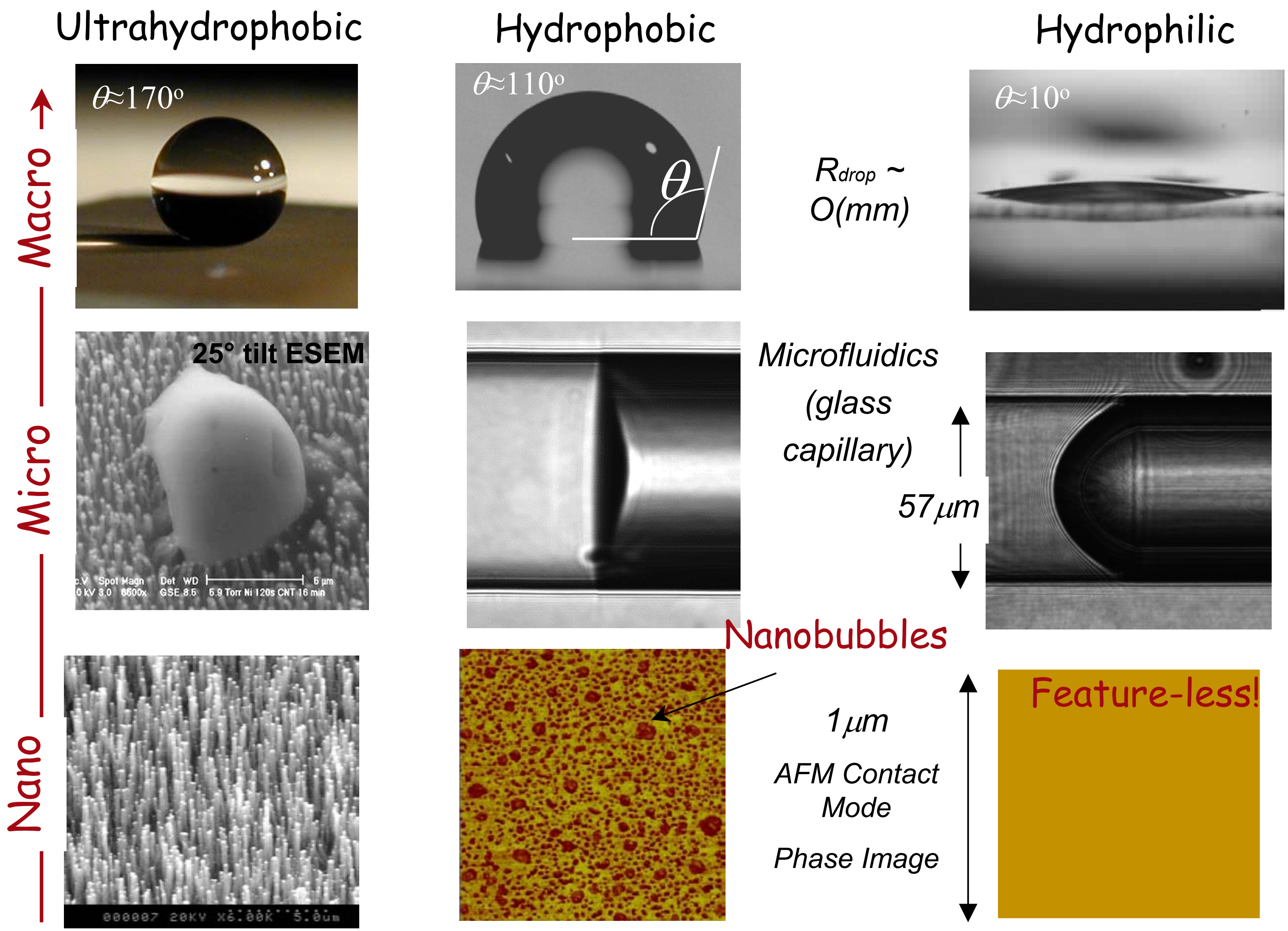
We seek to be able to manipulate the effective **boundary condition** at the fluid-solid interface; from the traditional one of 'no slip' to an adjustable partial-slip-like condition.

We achieve this control through nano-patterning of surfaces; incorporating both a controlled nanoscale roughness as well as patterning of hydrophobic and hydrophilic regions

The lowermost image in the middle row shows an image of **nanobubbles** (voids of roughly 30-50nm dimensions that have recently been discovered to form *spontaneously* on a hydrophobic surface in contact with water



K. Teo *et al.* Nanoletters, 2003

G.H. McKinley (NIRT on Nanowetting)

The MIT portion of the NIRT effort is focused primarily on engineering applications of nanowetting control in (a) microfluidic devices as well as (b) macroscale engineering applications.

The slide shows the application and consequences of these ideas from the macro-scale (top row) to the microscale in microfluidic geometries (middle row) to the nanoscale (lower row) for the cases of hydrophilic surfaces (righthand column), chemically-modified hydrophobic surfaces (middle column; here corresponding to silica surfaces coated with OTS (octadecyl trimethyl silane) and finally 'ultrahydrophobic surfaces' (which combine chemical treatment AND nanoscale roughness (leftmnost column). In this case the nanoscale roughness arises from a 'nanograss' of vertically-aligned multiwall carbon nanotubes grown on the surface using CVD and then coated with Teflon. This particular part of the slide was funded separately by the Cambridge-MIT Alliance (CMI) **prior** to the NIRT award. In year2 we plan to develop similar surfaces using the nanopatterned block-copolymer surfaces being developed in the NIRT by U.Mass-Amherst.

The lowermost image in the midrow shows an image of nanobubbles (voids of roughly 30-50nm dimensions that spontaneously form on a hydrophobic surface in contact with water - as a result of dissolved gas. The experiments are performed using a multimode AFM in tapping mode in conjunction with a fluid cell. Ongoing work includes extending these studies to nano-patterned surfaces and surfaces with controlled patterns of varying hydrophobicity. By controlling the density and topology of nanobubbles at interfaces we hope to control the macroscale frictional properties of these surfaces.

Staffing: 1 grad student Mr.. A. Agrawal (Dr J. Bico was partially supported by the Cambridge MIT Alliance prior to start of the NIRT)

Control of Wettability from the Nano to Micro to Macro-scale

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Education:

One graduate student at MIT is being trained in the specialized techniques required for study of liquid surfaces at the nanoscale (tapping mode AFM in liquids, laser feedback interferometry (LFI)) and microfabrication techniques for producing microfluidic devices with controlled surface properties

Societal Impact:

By modifying the interfacial boundary condition at the nanometer scale, it is possible to control the macroscopic frictional properties of a surface. In the future this offers the possibility of reducing the turbulent drag on submerged objects arising from fluid friction and lowering the energy consumption associated with viscous dissipation.